Fire and Fertilizer as Alternatives to Hand Thinning in a Natural Stand of Precommercial-Sized Loblolly Pine

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ABSTRACT. *A winter backing fire thinned a natural 4-yr-old loblolly pine (*Pinus taeda *L.) stand from below but reduced stem density less than did hand thinning. Application of nitrogen fertilizer did not accelerate natural thinning over the 4 yr test period. Burning and fertilizing increased dbh growth of crop trees, but gains were less than those produced by hand thinning. Height growth of crop trees was increased by fertilization but may have been reduced by burning. A case study showed that economic returns from prescribed burning were comparable to those from hand thinning for a 30-yr rotation. However, additional research is needed to produce prescription guidelines that minimize the risks of burning young stands before the practice can be recommended. South. J. Appl. For. 19(1): 5–9.*

Natural regeneration of loblolly pine (*Pinus taeda* L.) is inexpensive and has ecological advantages and thus is accepted as an alternative to planting. On the Coastal Plain, large seed crops are produced almost every year (Langdon 1981) and often give rise to dense stands that require precommercial thinning. Sapling-sized stands in the region are often hand thinned with chainsaws or shoulder-mounted circular saws. However, this method is labor intensive and expensive. Prescribed burning would be a low-cost method of precommercial thinning and was recommended by McNab (1977) for stands of pole-sized loblolly pine and by Nickles et al. (1981) for mixed stands of shortleaf pine (*P. echinata* Mill.) and hardwoods. Fertilizer application might accelerate natural thinning by speeding height growth of dominant trees and shading of smaller trees. Fertilization could be more economically attractive than hand thinning but has not been studied.

This study compares hand thinning in a dense 4-yr-old natural stand of loblolly pine to prescribed burning and application of nitrogen fertilizer as alternative methods of thinning. Mortality from prescribed burning and first-year growth of survivors were described by Waldrop and Lloyd (1988). This paper compares periodic stand growth for 4 yr after treatment (ages 5 to 8) for all treatment combinations. It also provides a case study that compares stand volumes and economic returns between treatments for a projected 30-yr rotation.

Methods

Study Area

Field work was done on the Santee Experimental Forest in Berkeley County, South Carolina. Soils are Aeric Achraquults of the Wahee series and are somewhat poorly drained and slowly permeable. Elevation is approximately 25 ft above mean sea level and slopes range from 0 to 4%. Site index for loblolly pine at age 50 is 90 ft.

The study site was clearcut in November 1981 after a winter backing fire and three annual summer burns. Logging slash was piled by hand and burned the following March. The area was then planted with loblolly pine seedlings on an 8 × 12 ft spacing for another research project that had been planned. The planned study was canceled, however, since pales weevil (*Hylobius pales* Hbst.) reduced survival of seedlings to only 11% (approximately 50 seedlings/ac). There was no need to replant the stand, however, because seedlings from seed in place and from adjacent stands fully occupied the site. After planting, the area was fertilized with 250 lb/ac of 0-46-0 triple superphosphate.

The study was established in the winter of 1985 to 1986 when the stand, almost all loblolly pine, was 4 yr old. Diameters at breast height ranged from less than 0.5 in. to 2.6 in. and averaged 0.6 in. Tree heights averaged 8.6 ft and ranged from less than 5 ft to 15.6 ft. Stocking of trees taller than 4.5 ft was approximately 7,400 stems/ac.

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Study Design

Prescribed burning, hand thinning, and no-thin (control) treatments were applied to three 0.4 ac (131 × 131 ft) plots in each of 5 complete blocks. Each of the 15 plots was split into 2 subplots (0.2 ac each) and 1 subplot in each pair received urea at 200 lb elemental N/ac. An additional 25 lb elemental P/ac was applied as triple superphosphate to ensure a maximum growth response to N. Prescribed burning was done with winter backing fires under conditions described below. In hand thin plots, pines with the largest diameters were tagged as leave (or crop) trees, with an average space per crop tree of 64 ft^2. All other trees were severed at ground level with shoulder-mounted circular saws. Similar sets of crop trees were tagged in control and fire-thinned plots for future growth comparisons. Selection of the trees with the largest dbh as crop trees consistently resulted in an acceptable spatial distribution of crop trees throughout treatment areas.

Burning Conditions

Prescribed burning was conducted on February 3, 1986, 4 days after a rain of 0.4 in. and 7 days after a rain of 0.9 in. A backing fire was set in each replication at approximately 12:30 PM Ambient temperature was 70°F and relative humidity was 38%. Winds were from the southwest at 3 to 5 mph. Fuels along the ground were light and moist, but the entire study area was covered by cured broomsedge (*Andropogon virginicus* L.), which carried the fires. Flame heights were 1 to 3 ft, and heat production was 6 to 26 BTU/sec/ft by Byram's flame length index (Brown and Davis 1973). Occasionally, flames reached 4 to 5 ft in height (116 to 188 BTU/sec/ft) where vertical fuels (broomsedge and needle drape) were heavy. The rate of spread ranged from 2.5 to 3.6 ft/min. with a mean over all replications of 3.0 ft/min. Burning was completed at approximately 1:30 PM, having covered almost 100% of the five burn plots.

Measurements

Prior to burning or hand thinning, a 0.04 ac permanent rectangular sample plot was established in each subplot. These plots were kept relatively small because the stand was dense. All sample plots were rectangular. However, plot dimensions were adjusted so that the plots did not include the few understocked holes in the stand. These adjustments ensured that treatment comparisons were uniform. Sample plots were located so there were adequate buffer areas between fertilized and unfertilized subplots.

Stand-level characteristics, such as mean dbh and height, were calculated from measurements of all trees over 5 ft tall in the 0.04 ac sample plots. Growth rates of individual trees could be determined only from crop trees, however, since these were the only trees that were tagged. Total height and dbh were measured on all trees (crop and noncrop) in sample plots during the fall of 1985, prior to hand thinning and burning. Burned plots were remeasured in May 1986, after budbreak and 3 months after burning, to identify fire-caused mortality. Trees in all sample plots were measured again in the dormant seasons of 1986–1987, 1987–1988, and 1989–1990 (at the end of 1, 2, and 4 growing seasons after treatment). Analysis of variance (α=0.05) was used to detect treatment differences in numbers of stems, dbh growth of crop trees, height growth of crop trees, mean dbh of all trees (crop and noncrop), and mean height of all trees.

Results and Discussion

Stand Development

Hand thinning reduced the total number of stems/ac from 7,600 to 675 (91%). Prescribed burning was less effective, reducing density from 6,800 stems/ac to 2,850 (58%). Post-thinning densities remained relatively constant throughout the 4-yr sampling period, with little ingrowth or natural thinning. In control plots, density increased from 8,800 stems/ac prior to the first growing season (1986) to almost 12,000 stems/ac by the end of the second growing season (1987) as trees grew into the 5 ft min. height class for measurement. By the end of the fourth growing season (1989), natural thinning had reduced density to 9,700 stems/ac. Fertilization did not increase or decrease stem numbers during the 4 yr sampling period for any of the thinning treatments.

Most stems that were severed in hand-thinned plots or killed by burning had small dbh (Figure 1). Burning reduced

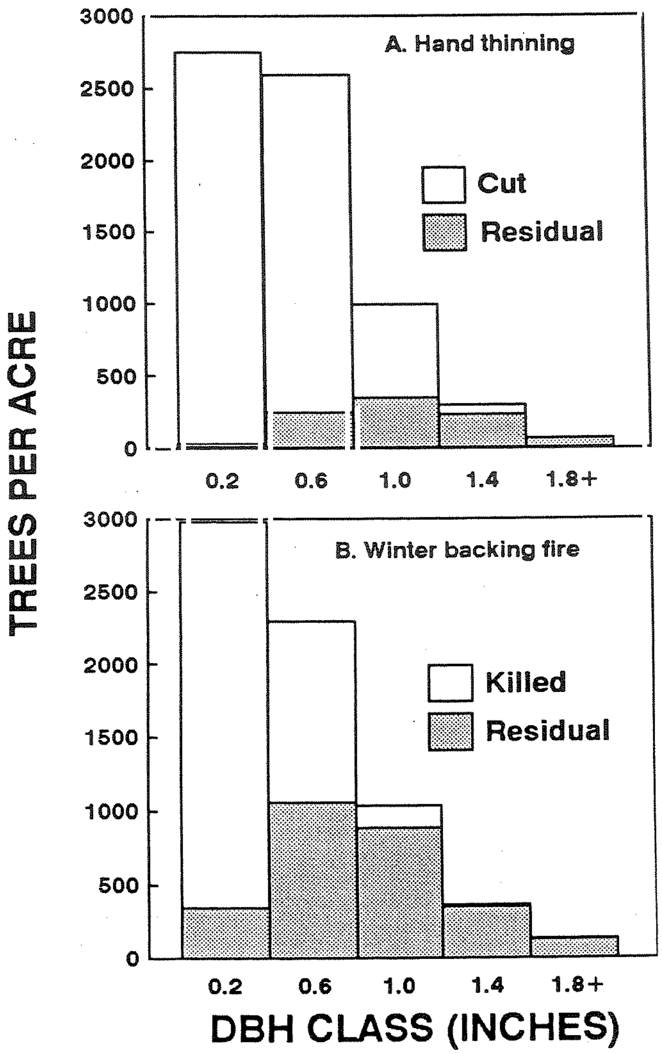

Figure 1. Change in dbh distribution of a natural 4-yr-old loblolly pine stand after (a) hand thinning and (b) a winter backing fire (all crop and noncrop trees).

stem numbers in the 0.2 in. dbh class by 88%, and hand thinning reduced stem numbers in that dbh class by almost 100%. Burning reduced densities in the 0.6 in dbh class by 58%, while hand thinning removed 90% of stems in that dbh class. For both treatments, the pattern of thinning was silviculturally desirable, resembling a thinning from below. Diameter distributions were changed from a skewed normal pattern, with large numbers of small trees, to a bell-shaped pattern in which medium-sized trees predominated (Figure 1).

The hand-thinning treatment was intended to produce stands about as dense as planted stands (nominal 8 × 8 ft spacing). Because only the largest trees were retained, mean stand dbh (crop + noncrop trees) was increased from 0.5 in. to 1.1 in. Mean stand height was increased from 7.2 ft to 9.4 ft. Even though prescribed burning substantially reduced the total number of stems, the stand was still dense, and immediate gains in mean stand dbh and height were less than in hand-thinned plots. Mean dbh of live trees in burned plots increased from 0.6 in. (prior to burning) to 0.9 in. (immediately after burning), and mean height increased from 7.3 ft to 8.4 ft. A burn of somewhat higher intensity might kill more small trees, producing a more satisfactory thinning. However, extreme caution is necessary because small increases in fire intensity can cause large increases in mortality.

Periodic growth of crop trees over the 4 yr of this study was increased significantly by both thinning treatments and by nitrogen fertilization (Table 1). Diameter at breast height (dbh) growth was 1.6 in. in control plots, 2.4 in. in burned plots, and 3.1 in. in hand-thinned plots. Fertilization increased dbh growth significantly in control and hand-thinned plots but not in burned plots. Height growth was expected to be greater in burned plots than in unthinned controls because the burned plots were thinned from below. However, height growth in the burn-only plots did not differ significantly from that in control plots, and height growth in the burn-fertilize plots did not differ significantly from the control-fertilize plots. There were reductions in height growth due to fire damage during the first growing season after treatment (Waldrop and Lloyd 1988) and these reductions may have continued for 2 or more years. Fertilization increased 4 yr height growth significantly in each of the thinning treatments.

Thinning and fertilization treatments produced stands with visually distinctive tree-size characteristics. At the end of the first growing season after treatment, mean stand dbh (crop + noncrop trees) ranged from 0.8 in. for control plots to 2.3 in. for plots that were hand thinned and fertilized (Figure 2). At that time, mean stand dbh for each treatment combination was significantly different from that for each other treatment combination, except that mean dbh for controls was not significantly different from that for the control-fertilize treatment. Because of differences in dbh growth, the range in mean dbh expanded over the 4 yr sampling period. After 4 yr, mean dbh was 1.4 in. for unfertilized control plots and 4.5 in. for hand-thinned fertilized plots. In all sample years, mean dbh was significantly higher in burned plots than in controls but was lower in burned plots than in hand-thinned plots.

Mean stand height (crop + noncrop trees) was also affected by treatment, but differences were less dramatic (Figure 3). At the end of the first growing season, trees in burned and hand-thinned plots were significantly taller than those in control plots, but fertilizer had produced no effect. After two growing seasons, a fertilizer effect was observed, and mean tree height for each treatment combination was significantly different from mean tree heights for all other combinations. By the end of four growing seasons, mean tree height was significantly greater in fertilized and unfertilized controls than in unfertilized burn plots. Damage from burning may have reduced height growth long enough to allow trees in control plots to catch up with those in burned plots. Also, natural thinning was observed in control and control-fertilize plots between years 2 and 4, but not in burned plots. Mortality in control plots was probably greatest among small trees, and high mortality among small trees would have increased mean tree height more than would growth differences alone. Trees in hand-thinned plots were significantly taller than those in unfertilized controls, unfertilized burned plots, and fertilized burned plots. Mean tree height was significantly greater in hand-thinned fertilized plots than in all other treatment plots in all sampled years.

Table 1. Mean dbh and height growth of crop trees by treatment for 4 growing seasons after treatments were applied (1986–1989).

Treatment	Mean dbh growth (in.)	Mean height growth (ft)
Control	1.6a[1]	14.0ab
Control/fertilize	2.1b	16.5cd
Burn	2.4c	13.8a
Burn/fertilize	2.6c	16.2c
Hand thin	3.1d	15.4bc
Hand thin/fertilize	3.6e	17.8d

[1] Means with the same letter within a column are not significantly different at the 0.05 level.

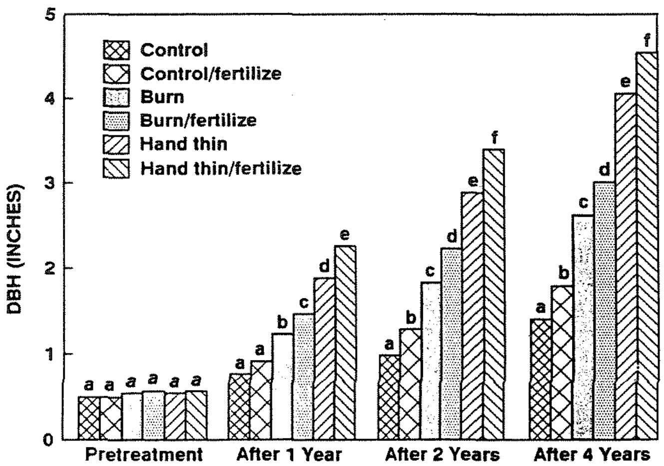

Figure 2. Mean dbh of all trees (crop and noncrop) by year and treatment. Means with the same letter within a year are not significantly different at the 0.05 level.

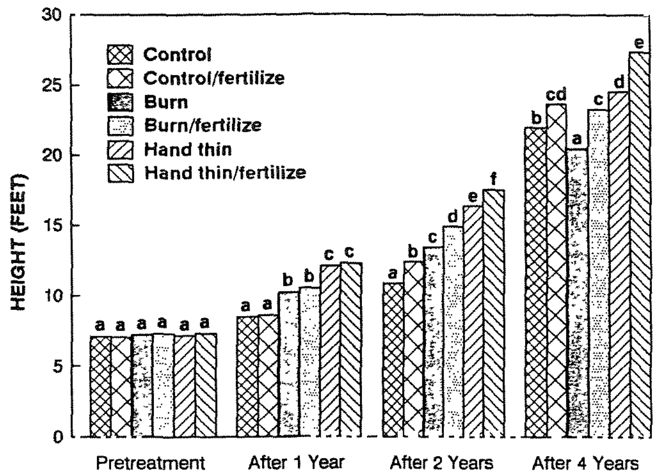

Figure 3. Mean height of all trees (crop and noncrop) by year and treatment. Means followed by the same letter within a year are not significantly different at the 0.05 level.

Case Study: Projected Volumes and Economic Returns from a 30-Year Rotation

If the differences in growth rates observed in this study continue over a number of years, the hand-thinned and prescribed burned plots will become more valuable than unthinned plots by the end of a rotation. Hand-thinned plots should produce more volume than control and burned plots, but these gains may not be worth the additional expense over prescribed burning. Conversely, prescribed burning could be the best investment but may not be worth the risk of burning in young stands.

A case study was conducted to compare stand volumes and economic returns that might be expected from each of the six treatment combinations for a 30-yr rotation. Stand characteristics measured at age 8 (1989–1990) were projected to age 30 by the GATWIGS model (Meldahl et al. 1987, Bolton and Meldahl 1990) for natural stands on the Lower Coastal Plain. Internal rates of return and net present values (using 4% and 8% discount rates) for all treatment combinations were calculated by GATWIGS. Cost estimates for prescribed burning, fertilization, and hand thinning were the average costs of these practices for the Southern Coastal Plain in 1986 (Watson et al. 1987) and are shown in Table 2. Prices for pine pulp and sawtimber were the averages reported by Neal and Norris (1989) for South Carolina in 1986. Returns were calculated from real prices, assuming no inflation and no real price change (Straka and Baker 1991). The default value of GATWIGS for management costs ($2/ac/yr) was accepted for all treatment combinations and was the only cost associated with the control treatment.

Table 2. Input values for GATWIGS parameters.

Costs (1986 dollars/ac)	
Prescribed burning	1.97[1]
Fertilization	37.14[1]
Hand thinning	54.00[1]
Annual costs (taxes and management)	2.00[2]
Returns (1986 dollars)	
Pine sawtimber (mbf Scribner)	148.00[3]
Pine pulp (cord)	14.90[3]

[1] Watson et al. (1987).
[2] Default value for the GATWIGS model (Meldahl et al. 1987).
[3] Neal and Norris (1989).

Economic comparisons were a marginal analysis designed to compare returns from thinning treatments alone, not to predict actual incomes. These values should not be compared with those of other forestry operations or other types of investments. Internal rates of return and net present values were chosen over soil expectation values for this case study due to the unique nature of the stand treatment. It was considered unlikely to have a perpetual rotation of greatly overstocked stands that were thinned or fertilized at age 4.

As suggested by the methods of Straka and Baker (1991), the marginal analysis was on a before-tax basis, and cost-sharing was not considered. Also, land costs were not included.

GATWIGS projected high mortality rates over the 22-yr simulation period, particularly for the control and control-fertilize treatments. Stem numbers for these treatments were reduced from 9,700/ac at age 8 to 1,010/ac and 818/ac at age 30, respectively (Table 3). Stem densities in control plots were greater than those used to develop GATWIGS, which may account for high projected mortality (Ralph S. Meldahl, personal communication). On burned plots, projected stem numbers decreased from 2,800/ac to approximately 600. Projected mortality on hand-thinned plots was less, with density decreasing from 675 stems/ac at age 8 to approximately 400/ac at age 30. Relative tree sizes and stand volumes between treatments remained the same over the projection period. Control plots had the smallest trees and lowest sawtimber volume, and the hand thin-fertilizer treatment yielded the largest trees and greatest volumes. Burning yielded greater volumes than the control treatments but somewhat less volume than the hand-thinned treatments at age 30.

All treatment combinations were considered to be worthwhile investments with internal rates of return over 11% (Table 3). The two least expensive treatments, unfertilized controls and burn only, gave the highest internal rates of return, indicating the greatest return on each invested dollar. Although the rate (IRR) decreased, total income from each stand (NPV) tended to increase with each additional investment. At a discount rate of 4%, investment in prescribed burning increased net present value, but not as much as did investment in hand thinning. Fertilization increased net present value for the control and hand-thinning treatments but decreased the value of burned plots. At the higher discount rate of 8%, hand thinning increased present stand value. However, the burn-only treatment was the best investment with a net present value of $171.97/ac. The low cost and growth increases associated with prescribed burning, combined with the higher discount rate, made additional investment in hand thinning or fertilization unnecessary.

Conclusions

Both hand thinning and prescribed burning effectively thinned a dense 4-yr-old loblolly pine stand. By removing

Table 3. **Stand characteristics and economic returns by treatment predicted by GATWIGS at age 30.**

Treatment	Stems/ac	Mean dbh (in.)	Sawtimber volume (mbf[1])	Pulp volume (cords)	IRR (%)	Net present value (1986 dollars)	
						4% discount	8% discount
Control	1,010	4.7	4.2	16.3	18.3	278.70	94.83
Control/fertilize	818	5.5	4.4	22.5	11.9	290.15	75.91
Burn	600	6.7	7.8	19.7	20.3	487.71	171.97
Burn/fertilize	568	7.1	5.8	29.7	13.0	396.63	114.61
Hand thin	403	8.4	8.7	25.3	13.0	512.91	148.87
Hand thin/fertilize	388	8.8	9.8	27.3	11.6	548.46	138.97

[1] Scribner rule.

small trees, both treatments significantly increased mean tree dbh and height. Dbh growth of crop trees was increased by both thinning treatments, and height growth was increased by hand thinning. Prescribed burning reduced height growth for at least 1 year. Nitrogen fertilization increased dbh and height growth of crop trees but did not accelerate natural thinning during the 4 yr of this study. Increased natural thinning may be observed in future growing seasons if fertilization gave crop trees a competitive advantage over smaller trees in control and burned plots.

The case study showed that hand thinning and prescribed burning could be good investments. These thinning treatments increased the net present value of the stand at both discount rates tested. Prescribed burning provided the greatest return on each dollar invested, with an internal rate of return of over 20% and the highest net present value of all treatment combinations when the discount rate was 8%. With a discount rate of 4%, both the hand thinning and hand thinning-fertilizer treatments provided higher net present values than did prescribed burning. Nitrogen fertilization did not consistently increase net present value.

Prescribed burning may become attractive to some landowners as an alternative to hand thinning due to its lower initial investment and higher internal rate of return. However, guidelines for prescribed burning in young stands do not exist, and the economic gains may not be worth the risk. Fire behavior is variable and can produce widely differing results, particularly in young stands. In this study, a fire of somewhat greater intensity would have accomplished a more complete thinning, which might have increased volume production and income. Incomes would have been smaller, however, for fires of lower intensity which leave a more dense stand or fires of high intensity which damage or kill crop trees. Assessments of risk and variability among fires were beyond the scope of this case study, and a more complete economic analysis may show prescribed burning to be less attractive than hand thinning. Even though hand thinning requires a large initial investment, economic returns projected in this study were comparable to returns from prescribed burning with little risk of stand damage. If prescribed burning is to be successful for thinning over a wide range of stand conditions, additional research is needed to develop guidelines and burning prescriptions.

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